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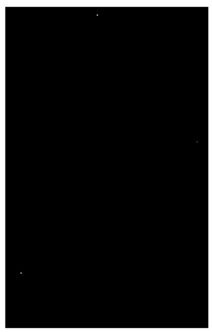

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 14 WHOI-81-2	2. GOVT ACCESSION NO. AD-A096	3. RECIPIENT'S CATALOG NUMBER 056
4. TITLE (and Subtitle): RADIO TAGGING OF FINBACK WHALES - ICELAND, JUNE-JULY 1980. 9		5. TYPE OF REPORT & PERIOD COVERED: TECHNICAL
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): 10 William A. Watkins		8. CONTRACT OR GRANT NUMBER(s): N00014-79-C-0071 AA851-CT0-23 (BLM)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, 02543 12		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: NR 083-004
11. CONTROLLING OFFICE NAME AND ADDRESS: NORDA-National Space Technology Laboratory, Bay St. Louis, MS 39529 11		12. REPORT DATE: January 1981
		13. NUMBER OF PAGES: 46
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report): Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

1. Radio whale tag
2. Tracking of radio tagged finback whales
3. Balaenoptera physalus

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In June and July, 1980, finback whales (Balaenoptera physalus) were radio tagged in the waters west of Iceland. One double-tagged finback was tracked continuously with shipboard receiving gear for 9-1/2 days, for over 2095 km, during which it swam with from one to seven companion finbacks to within 130 km of Greenland. The tagging and tracking systems worked well. New behavioral information about finbacks was gathered, and new questions were raised concerning this population's movements and distribution. Whale integument is discussed and the potential retention of transcutaneous whale tags is analyzed.

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WHOI-81-2

RADIO TAGGING OF FINBACK WHALES - ICELAND, JUNE-JULY 1980

by

William A. Watkins

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts 02543

January 1981

TECHNICAL REPORT

Partially funded by the Bureau of Land Management of the U.S. Department of the Interior under Contract AA851-CTO-23 and the Oceanic Biology Program of the U.S. Office of Naval Research Contract N00014-79-C-0071; NR 083-004, the Marine Research Institute, Reykjavik, Iceland and the Iceland Whaling Company.

Approved for Distribution: George Grice
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Department of Biology

Radio tagging of finback whales - Iceland, June - July 1980

Page

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Abstract

In June and July, 1980, finback whales (Balaenoptera physalus) were radio tagged in the waters west of Iceland. One double-tagged finback was tracked continuously with shipboard receiving gear for 9 1/2 days, for over 2095 km, during which it swam with from one to seven companion finbacks to within 130 km of Greenland. The tagging and tracking systems worked well. New behavioral information about finbacks was gathered, and new questions were raised concerning this populations's movements and distribution. Whale integument is discussed and the potential retention of transcutaneous whale tags is analyzed.

Key words: Radio whale tag

Tracking of radio tagged finback whales

Balaenoptera physalus

Denmark Strait

Iceland-whale tagging

1. Acknowledgements

The Iceland radio whale tagging experiment was designed to study the "effects of whale monitoring system attachment devices on whale tissues", and was funded by the Bureau of Land Management (BLM) of the U.S. Department of the Interior (Contract AA851-CTO-23) and the Oceanic Biology Program of the U.S. Office of Naval Research (ONR) (Contract N00014-79-C0071 NR 083-004). The field experiment was conducted with the help of the Marine Research Institute, Reykjavik (Jón Jónsson and Jóhann Sigurjónsson). The Iceland whaling company, Hvalur, H.F., provided hospitality and space for the tissue sampling program, and gave us one of their whale ships for three days for the tagging. The crew of the whaler, *Hvalur 6*, under Sigurbjörn Árnason, and the crew of our chartered tracking vessel, *Ljósfari*, under Hákon Ísaksson, provided expert and gracious support. We particularly appreciated the special care given to us by Kristján Loftsson of the whaling company and the helpfulness of Jóhann Sigurjónsson, who shared in the experiences of both the tagging and tracking exercises. The experiment was possible because of the complete support of our Icelandic colleagues.

The tagging hardware was made by Ocean Applied Research Corporation (OAR), San Diego and by Romaine R. Maiefski, engineering consultant, Encinitas, California. Maiefski also did most of the tagging in Iceland. One tag was implanted by the skipper of *Hvalur 6*, Sirgurbjörn Árnason.

The tagging and tracking team worked well together:

Jóhann Sigurjónsson, Marine Research Institute, Reykjavík

Douglas Wartzok, The Johns Hopkins University, Baltimore, Maryland

Giuseppe N. di Sciara, Hubbs-Sea World Research Institute, San Diego, CA.

Greg Maiefski, Metrum, Encinitas, CA.

Romaine R. Maiefski, Metrum, Encinitas, CA.

Richard H. Lambertsen, Woods Hole Oceanographic Institution.

Karen E. Moore, Woods Hole Oceanographic Institution.

William A. Watkins, Woods Hole Oceanographic Institution.

We appreciated the help of Harriette Izenberg and Wesley Wilcox of the University of Pennsylvania's Veterinary School Laboratory of Microbiology in developing the microbiological protocol for tissue samples.

Karen E. Moore helped with the preparation of this report, particularly attending to the photography, tracking and radio signal analyses. Jean E. Maguire (VMD) has done the literature search and along with Richard H. Lambertsen (VMD, PhD) provided the analysis for our assessments of tissue reaction.

2. Introduction

Positive identification of individual whales is necessary for a realistic understanding of their distribution and behavior and for population assessments. Such identifications are difficult at best, since natural marks that clearly distinguish individuals in a whale population are only occasionally available and depend on uncertain visibility for recognition. Radio tags for whales, therefore, have been developed to provide the positive identification that is needed and to allow tracking of the whales' movements from a distance.

The tag that we are developing is remotely implanted from a shoulder gun into the blubber, with only the antenna protruding. The tag transmits a signal each time the whale approaches the surface closely enough to expose the antenna above water. The development of this tag and details of its construction and circuitry are given by Watkins, Wartzok, Martin, and Maiefski (1980). The tag transmitters operate in the 27 to 30 MHz range and tracking is by automatic direction-finding (ADF) receivers and antennas. The tag transmitters and the tracking equipment are made by OAR, and Romaine R. Maiefski (engineering consultant, Encinitas, CA.) provided much of the mechanical detail of the tag launching and attachment systems. The development has been a team endeavor with input from several investigators, organized by the Woods Hole Oceanographic Institution (WHOI).

Previous experiments with the WHOI/OAR tag included two series of tests on whale carcasses in Iceland in 1976 by Watkins and Schevill (1977) and in 1977 by Watkins and Moore (Watkins 1979). This (WHOI/OAR) tag was

tested on finback whales in 1976 in the St. Lawrence River, Canada, by Ray, Mitchell, Wartzok, Kozicki, and Maiefski (1978). Tests of this tag also were made on humpback whales during experiments in 1976 and 1977 near Juneau, Alaska, by Johnson, Tillman, Wolman, Rice, Jurasz, and others (Marine Mammal Division, National Marine Fisheries Service, 1976, 1977). In 1978 a more comprehensive experiment was conducted in Prince William Sound, Alaska (Watkins, Johnson, and Wartzok 1978). Both finbacks and humpbacks were tagged and tracked as long as the tags remained in place, for two to three weeks. Behavioral reactions of the whales to the tagging were reported (Watkins, in press) and the tracking details were analyzed (Watkins, Moore, Wartzok, and Johnson, in press). The relatively short retention of the tag was thought to be primarily due to hydrodynamic drag although tissue mechanisms also probably contributed (see discussion of tissue reaction below). The tag was redesigned to reduce drag by implanting below the skin, and to increase the holding projections by a new "hula-skirt" attachment. A field experiment testing these changes was made on Bryde's whales (Balaenoptera edeni) off Venezuela in 1979. This test indicated improvement in both tracking and tagging systems but we were unable to follow the tagged whales for long (Watkins, di Sciara, and Moore 1979). More extensive tests of all phases of the radio whale tag were needed to be sure that the implantation and holding systems would work well. In addition, it was apparent that a study of the reaction of whale tissues to a transcutaneous tag would be needed if long-term tag retention were to be achieved.

Details of the tagging system and tagging procedures, the radio tags, the attachment system, and the ADF radio tracking arrangements are given in the following publications. The references that are listed also show the development and testing of this WHOI/OAR radio whale tagging system.

Schevill, William E. and William A. Watkins. 1966. Radio-tagging of whales. Ref. No. 66 - 17, Woods Hole Oceanographic Institution, Woods Hole, Mass, 15 pp., 10 figs.

Ray, G. Carleton and Douglas Wartzok. 1975. Tests of an implantable beacon transmitter for use on whales. Report to the National Marine Fisheries Service in compliance with the Endangered Species Permit No. E4 and Marine Mammal Permit No. 99. The Johns Hopkins University, 8 pp.

Marine Mammal Division, NMFS. 1976 and 1977. Radio-tagging of humpback whales. Report to the National Marine Fisheries Service (NMFS) in compliance with Permit No. 136. Northwest and Alaska Fisheries Center, NMFS, Seattle, 4 pp.

Watkins, William A. and William E. Schevill. 1977. The development and testing of a radio whale tag. Ref. No. 77 - 58, Woods Hole Oceanographic Institution, Woods Hole, Mass., 38 pp.

Watkins, William A. 1978. A radio tag for big whales. Oceanus, 21 (2), pp. 48 - 54.

Ray, G.C., E.D. Mitchell, D. Wartzok, V.M. Kozicki and R. Maiefski. 1978. Radio tracking of a fin whale (Balaenoptera physalus). Science, 202, pp. 521 - 524.

Watkins, William A., James H. Johnson, and Douglas Wartzok. 1978. Radio tagging report of finback and humpback whales. Ref. No. 78 - 51, Woods Hole Oceanographic Institution, Woods Hole, Mass., 13 pp.

Watkins, William A. 1979. A point for penetrating whale blubber. Deep-Sea Research, 26, pp. 1301 - 1308.

Leatherwood, Stephen and William E. Evans. 1979. Some recent uses and potentials of radiotelemetry in field studies of cetaceans. Pp. 1 - 31, in: Winn, Howard, E. and Bori L. Olla (Eds.), Behavior of Marine Animals. Vol. 3. Plenum Press, New York.

Watkins, William A., Giuseppe N. di Sciara, and Karen E. Moore. 1979. Observations and radio tagging of Balaenoptera edeni near Puerto La Cruz, Venezuela. Ref. No. 79 - 89, Woods Hole Oceanographic Institution, Woods Hole, Mass., 8 pp.

Watkins, William A., Douglas Wartzok, Hugh B. Martin III, and Romaine R. Maiefski. 1980. A radio whale tag. Pp. 227-241, in: Diemer, Ferdinand P., F. John Vernberg, and Donna Z. Mirkes. (Eds.), Advanced Concepts in Ocean Measurements in Marine Biology, Belle W. Baruch Library in Marine Science, No. 10, University of South Carolina Press, Columbia, S.C.

Watkins, William A. In press. Reaction of three species of whales to implanted radio tags, *Balaenoptera physalus*, *Megaptera novaeangliae*, and *Balaenoptera edeni*. Deep-Sea Research.

Watkins, William A., Karen E. Moore, Douglas Wartzok, and James H. Johnson. In press. Radio tracking of finback (*Balaenoptera physalus*) and humpback (*Megaptera novaeangliae*) whales in Prince William Sound, Alaska. Deep-Sea Research.

3. Purpose of the Iceland Radio Tagging Study

The purposes of the radio whale tagging in Iceland waters were (1) to study the effects of implanted tags on whale tissues, (2) to test the modifications to the radio tagging and tracking systems, (3) to assess the potential retention characteristics of the radio tag, (4) to assess the capabilities of the system in open-sea tracking conditions, and (5) to gather data about the distribution and behavior of the pelagic finback whale population off Iceland.

4. Preparations for the Iceland Experiment

The Iceland experiment was a joint effort with Icelandic and U.S. investigators interested in the development of a radio tag for whales. The experiment was outlined in our (WHOI) ONR proposals for 1979-1980 and 1980-1981, and it was described in more detail in our BLM proposal of 12 March 1980. The sequence of events in the field was given in the "Field report - Icelandic radio whale tagging, tracking and tissue reaction experiment - 19 June to 10 July, 1980" (distributed 4 August 1980).

Finback whales (*Balaenoptera physalus*) were to be tagged with radio transmitters (with the help of the Icelandic whalers). One of the tagged whales would be tracked for up to two weeks, and the capability of the WHOI/OAR radio tag system and its modifications would be assessed. Then after the tagged whales were taken by the Icelanders as part of their yearly catch, the tissues surrounding the implanted tags would be sampled and analyzed. By continuous tracking, the whereabouts of at least one tagged whale would be assured so that we could be certain of obtaining tissue samples.

Preparations for the experiment included: (1) detailed plans for tissue and biologic sampling of the area surrounding the tags, (2) transportation and handling arrangements for the tissue samples, (3) U.S. and Icelandic permits for the experiments, (4) fabrication of the modified radio tags with a variety of attachment systems to be tested, (5) assembly of both the tagging and tracking equipment, (6) charter of the tracking vessel, (7) interaction with Icelandic personnel to facilitate their participation in all aspects of the tests, and (8) organization of

experienced personnel for all phases of the program. For complete success, it was realized that we would need nearly ideal conditions for the tissue work, tagging and tracking equipment that performed well, help from the Icelandic researchers and whalers, good weather, and (above all) cooperative whales. This was to be our first open-sea whale tagging and tracking effort.

The field party was to be divided between the tagging and tracking boats. The tagging crew would go aboard one of the Icelandic whale catchers for three days and tag several finback whales with radio tags, more than one tag per whale when possible. One of the whales would be chosen for continuous tracking. The tagging crew would transfer at sea (weather permitting) to the tracking boat to help track that whale. A veterinarian would remain at the Icelandic shore whaling station ready to collect and prepare tissue samples and microbial cultures from the tagged whales that were caught and brought to the station. Finally, the whale that was tracked for the extended period would be taken by the whalers so that the tissue surrounding these tags could be analyzed.

Preparation for tissue sampling began at Woods Hole and the University of Pennsylvania with the development of a complete field sampling protocol by Jean Maguire (VMD) and Richard Lambertsen (VMD, PhD). Permits were obtained from the National Marine Fisheries Service, Office of Marine Mammals and U.S. Department of Agriculture, Veterinary Services as well as from the Icelandic Veterinary Services and Icelandic Ministry of Fisheries. The Marine Research Institute in Reykjavik contributed sampling supplies. Plans for preliminary tissue analysis were made with a pathology

laboratory near Woods Hole and the microbiological laboratory of the University of Pennsylvania Veterinary School. Dr. Maguire would handle the samples sent from Iceland, and Dr. Lambertsen would prepare the samples in Iceland. At the whaling station at Hvalfjörður, Iceland, preparations were made for careful tissue sampling and photographic documentation. Depending on the success in obtaining tissue samples from the sites of implanted tags, other laboratories also were prepared to analyze and assess the tissue reactions (R.J. Harrison's laboratory in Cambridge, England, for example).

Preparations also were made for photographic documentation of the tagging and tracking activities, including 16 mm movie and 35 mm still photography. For navigation and tracking, we planned to use Loran C and ADF receiver plots and signal recorders. For tagging, we were prepared to implant two tags simultaneously, and the tags were fitted with a variety of attachment configurations in order to compare their holding characteristics. We also wanted to compare the two types of antennas on the whale tags - the antenna used in previous experiments and a newly modified antenna with higher output at lower angles to the water. Tracking of one whale was to be continuous, and personnel schedules and equipment were arranged to make this feasible.

The whaling company would provide one of their whale ships, Hvalur 6, a 46-m vessel, and its crew for our use in locating and tagging the whales. We hoped to tag several whales, each with two or more tags. For multiple tagging of the same whale we felt certain that we would need the whalers' expertise in spotting and maneuvering.

An Icelandic capelin fishing vessel, the 40.5-m _Ljósfari_, was chartered as the tracking boat. Fuel costs were to depend on the distance and speed requirements for tracking the tagged whale.

5. The Field Trip

The trip to Iceland 19 June to 10 July 1980, was summarized in our 4 August 1980 field report. The Ljósfari, tracking boat, left harbor on 23 June to begin spotting whales and to prepare to track the radio tagged finbacks. Two ADF multichannel receivers (OAR model 922) were installed and an ADF Adcock (OAR) antenna was mounted above the mast, approximately 12 m above the water. Both receivers were connected to the same antenna, and they were powered by a low-voltage (12 v DC) converter and transformer from the ship's 230 v AC system. Radio signals from both receivers were recorded on an event recorder (modified Rustrak) along with time. Each receiver was equipped to monitor all of the tag frequencies (27 - 30 MHz) and two back-up receivers also covered these frequencies . We carried complete spares including antenna. Douglas Wartzok, Greg Maiefksi, and Giuseppe N. di Sciara were on board to begin tracking. They were to remain with the tagged whale even if rough sea conditions prevented our tagging crew from transferring to the Ljósfari.

At the whaling station, Richard Lambertsen set up a tissue sampling program and examined the one to six finbacks per day that were brought to the station for processing. Arrangements were made for rapid handling and transport of tissue and microbiologic samples to the U.S. laboratories when a tagged whale was brought to the station. Preparations also were made for aerobic and anaerobic bacterial isolation, macrophotography, and tissue sampling at the station laboratory, at the Reykjavík Marine Research Institute, and the Icelandic Veterinary Pathology Laboratory.

The tagging boat, Hvalur 6, departed on 24 June as the weather improved. William Watkins, Karen Moore, Romaine Maiefski, and Jóhann Sigurjónsson were aboard for the round-the-clock three-day tagging effort.

As the Hvalur 6 (Fig. 1) steamed toward the catch area (63°16'N, 25°50'W, 300 km SW of the station), practice shots with dummy tags at floating targets were made using realistic boat maneuvering. There were 10 practice shots providing calibration of equipment and shooters, and we decided that it was feasible to try double-tagging — two shooters tagging the same whale in two locations simultaneously. Although the catcher boat was very maneuverable, it was a relatively large vessel and the possibility that it might not be able to get close enough to the elusive finbacks began to be apparent. We realized that there might be only one chance to tag, since an approach to within 30 m of the tag site was necessary. For implantation one to two meters behind the blowhole of a 20-m finback, therefore, we would have to approach to within 10 m of the whale. This close approach would also have to coincide with the whale's surfacing (tag will not implant after being slowed by passage through water) and finbacks usually dive before any vessel gets very close.

We found four species including finbacks (Balaenoptera physalus, B. musculus, Megaptera novaeangliae, and Physeter catodon) in the Icelandic whaling area. Local knowledge assured us that the finbacks were part of the population harvested by the whalers, and that these whales gradually moved northward along the west coast of Iceland as the season progressed, and did not leave the general whaling area.

Tagging was by two shooters from the bow of the whale ship. The tag transmitters were tested, made ready for firing, and attached to their pushrods and colored streamers before being brought out on deck (Fig. 2). A variety of holding arrangements were used. The tags were mounted in the guns and sprayed with liquid zephiran chloride, a disinfectant. Shooters and photographers remained on the bow of the ship prepared for the close approach that could bring a whale at any moment within range of the tagging system. We remained ready to tag at very short notice.

Because of the underwater noise produced by the large ocean-going whaling vessel it was impossible to move quietly toward the whales. The best approach to these pelagic finbacks was first to assess the surfacing behavior of the whales and then try to slowly cross the track of one whale at a position that coincided with its next surfacing. Successful approaches for tagging have been found to vary with species and with the activity of individual whales prior to tagging. Experienced personnel have been needed for all phases: behavioral observations, judgement of whale size, estimates of distance to the surfacing whale (required for vertical tagging accuracy), operation of the tagging equipment, assessment of the effect of the tag on the whale's behavior, and tracking procedures.

The radio tag (Fig. 3) was attached to a pushrod inserted into the tagging gun. After implantation, the pushrod was released and pulled back by a retrieval line that payed out of a cannister mounted on the gun barrel. The line also served to retrieve tags that missed. Each of the radio tags had a brightly colored streamer (5 x 60 cm) attached -- a different color on each tag so that the tagged whales could be recognized visually. The components of the whale tag are identified in Figure 3.

Tagging proved to be very difficult. Only occasionally could we get as close as 35 or 40 m from a surfacing finback. Hours of stalking were required for each tagging attempt, and sometimes though our distance judgments were only a meter off, the tag fell short or ricocheted because the trajectory angles were too low. All of the tagged whales were large, at least 18 m in length.

There were 16 tagging attempts on 10 finbacks. The radio tag sequence is given in Table 1. Three whales were successfully tagged (indicated in Table 1 by asterisks). Whale #2 was double-tagged (two tagging guns) but the tags were not placed high enough for reliable tracking so we decided to try again. Whale #6 was tagged with one tag (Fig. 4) which did not appear to transmit well after implantation and we were not successful in approaching that whale for a second tagging. Whale #7 was tagged near the fin (Fig. 5), a site that would not be regularly exposed by a finback. We continued to try to tag and finally were successful. After 14 hours of tracking and several attempts to maneuver into tagging position, a second tag was placed in a good position on whale #7, 3 m behind the blowhole. Because of the time and distances travelled during tagging approaches, it was not possible to stay with more than one tagged whale. It was hoped however, that all of the tagged whales could be relocated at a later time.

After whale #7 was tagged the second time and it was determined that both of the tags on this whale were operating well the tagging crew transferred at sea to the Ljósfari.

During tracking, the Ljósfari usually remained 1 to 5 km from the whale, periodically approaching closer for photography of the tag sites or

for behavioral observations. We did not follow the whale, but remained to the side and slightly to the rear of its path, usually keeping the tagged whale on a relative bearing of 45°. The tracking ship seemed to have no effect on the whale's course; even when we deliberately crossed its path close ahead of it, the whale and its companion finbacks simply dove under the ship and continued on their course. Continuous tracking was not limited by sea conditions, which reached wave heights of 5 to 6 m. Distance for good tracking depended on sea state, but was consistent to at least 15 km. In order to stay with the whale, we purposely did not test these ranges for maximum distance.

The tagged finback was continuously tracked for 2095 km (1131 nautical miles) throughout 9 days and 10 hours (2200, 25 June to 0800, 5 July). After a day of feeding with other whales (both finbacks and blue whales, Balaenoptera musculus) on dense krill concentrations, the tagged finback left the Icelandic area. It swam west across the Denmark Strait and began feeding apparently on schooled fish in an area roughly 130 km from Greenland (see track, Fig. 6). It remained in Greenland waters for the last half of the radio track, moving back and forth along the meandering front between the East Greenland and Irminger Currents, over an area of steeply sloping bottom. The whale travelled as much as 292 km per day (1 July). Throughout the track across the Denmark Strait it was often found in the company of one to seven other finbacks.

Signals from both tags were used in tracking whale #7 (a 20-m whale). The "neck" tag with a yellow streamer was located on the back 3 m behind the blowhole and approximately 25 cm to the right of the midline. This

tag transmitted at a frequency of 27.520 MHz and was implanted at a relatively low (30°) angle from horizontal. The "fin" tag (Fig. 5) was on the left side at the base of the fin, and its antenna was angled to the side, standing out at approximately 45° from horizontal. The fin tag transmitted at 27.420 MHz and was fitted with a newer antenna, designed to give 6 to 12 dB more output than the "neck" tag (older antenna design) at the same antenna angles. Each tag was monitored by a separate receiver which gave relative bearings to the tagged whale, and the radio signals were recorded on separate channels of the paper recorder. On a final "round-out" surfacing before a dive, the "neck" tag transmited first as it was lifted out of water, then shut off as it was submerged. A few seconds later, the "fin" tag would begin to transmit until it too was submerged as the whale dove.

The continuous monitoring and recording of the radio signals from the two tags provided an indication of the whale's surfacing patterns and behavior. A sample page of the signal plots is given in Figure 7. The signal sequences are typical and cover the period of 1925 on 30 June to 0255 on 1 July. Each group of signals from one surfacing is indicated in Figure 7 as one slanted line, time being represented by the base of each line and plotted on a scale of 1 cm/2 min. Antenna exposure was highly variable (1 to 8 pulses) but usually provided two to four transmitter pulses. At a rate of 2 pulses per second the average antenna exposure was 1 to 2 sec. The radio signals of the "neck" tag (Fig. 7, top sequence of each row) gave an approximation of respiration times but were not always directly related since the whale sometimes blew without exposing

the tag antenna (though the tag was located only 3 m behind the blowhole), and sometimes the antenna protruded above the surface without the whale blowing. Often there was only partial exposure of the antenna. The "neck" tag was more frequently exposed than the "fin" tag and in some parts of the track was our only signal source. Signals from the fin tag (Fig. 7, plotted as the bottom sequence of each row) were heard only when the fin broke the surface, and especially in rough water this sometimes was the only part of the whale exposed. There were some long periods of approximately 20 min without tag signals, but intervals generally did not exceed 10 min. More detailed analyses of the radio track and signal sequence data will be published later.

We remained with the tagged whale as long as possible. When we left (0800, 5 July) both transmitters were still operating well. The finback had moved to 64°30'N, 36°30'W, out of reach of the Icelandic whaling operation, 700 km from the whaling station (see Fig. 6). Even if the tagged whale could have been taken, the length of its tow (40 hrs or more) to the shore station would have been three to four times that required for use by the whaling station, and for good tissue analysis. Only during the first two days of this track would it have been possible for the whalers to have taken and used the whale, but that would have been too soon for meaningful analysis of the tissue reactions. The whale had moved steadily from the Icelandic whaling grounds into the jurisdiction of Greenland so that its capture was legally impossible without prior diplomatic clearance. Although, as was noted above, we found that we could not influence the whale's direction of travel we kept hoping that the whale

would turn back, but the tagged whale and its companions gave no indication of leaving the East Greenland waters. The charter was finished (three days tagging, ten days tracking, and two days returning). An extended track was impossible due to logistics, extra charter and operational costs, and the whale's location.

The tags were still in place when we left, and there was no visible change from their original orientation throughout the ten days. The blubber and skin remained tightly closed over the body of the tags with only the antennas protruding. The antenna angles had not changed. There was no sign of infection or rejection, and the tags had not loosened their hold. The "fin" tag had been fitted with toggles at its base and the "neck" tag had a "hula-skirt" attachment at the middle of the stainless steel housing — both tags were rigidly held in place. This was a real improvement over the previous tests on finbacks in which the tags had changed orientation within hours, loosened, and gradually worked outward with time. The tag modifications that reduced hydrodynamic drag (removal of the flange) and that set the body of the tag under the skin had made a significant improvement in retention. It is possible that these tags are still in place and still transmitting since each tag had an estimated 12 month battery supply.

We had hoped that the whalers could find and capture the tagged whales before their catching season ended in September. Arrangements were made for complete tissue sampling from around the tags in the event that the whales were taken. The whaling season ended, however, without any of the tagged whales being found.

6. Whale Skin and an Implanted Tag

Reviewing the characteristics of cetacean skin is helpful to appreciate the potential problems faced in the use of a transcutaneous whale monitoring device (radio tag). The integument of cetaceans may be divided (Ling 1972) into five distinct zones, starting with the outermost -- the epidermis, dermis, hypodermis, cutaneous musculature, and the superficial fascia (see also Sokolov 1960; Simpson and Gordon 1972, Parry 1948). The inner layer consists of a loose network of connective tissue attaching the integument to the deep body musculature. The cutaneous musculature (pannulus carnosus) is composed of three distinct sheets covering separate body areas. The hypodermis which in rorquals represents the major blubber layer, consists of a fibrous collagen lattice-work invested with varying numbers of fat cells. Externally this fibrous lattice-work is continuous with the reticular layer of the dermis. Internally the collagen fibers continue to the cutaneous muscle layer as relatively loose connective tissue. The dermis is primarily composed of thick bundles of collagen fibers running parallel to the skin surface and interspersed with elastin fibers. The epidermis (less than 1 mm to 2 cm thick, depending on the species) has three distinct layers of cells, compared to five in most other mammals. Keratinization of these cells towards the skin surface is incomplete, and does not produce a distinct stratum corneum as seen in terrestrial mammals. The mitotic rate of epidermal cells in cetaceans is high, as we found in marking delphinids with paint (Watkins and Schevill 1976); Palmer and Weddell (1964) estimated the rates in _Tursiops_ skin to be up to 250 to 300 times that of

human skin (see also Harrison and Thurley 1972). The degree of vascularization and innervation of cetacean skin is dependent on both the species and the anatomical location (Giagometti 1959, Palmer and Weddell 1964, Parry 1949).

A notable feature of the skin of both toothed (Odontoceti) and baleen (Mysticeti) whales is the prominent development of the papillary circulation of the dermis, probably as a thermoregulatory mechanism (Simpson and Gardner, 1972). Dermal pegs (papillae) in cetaceans extend nearly to the skin surface. Circulation to the integument probably varies with diving behavior (as a result of peripheral vasoconstriction (Elsner, 1969), and body heat load.

Thus, the skin of cetaceans is a physiologically dynamic organ composed of several layers, each somewhat distinct in structure. In life, it is in motion (Essapian, 1955). Dorsal and ventral flexion of the spine as occurs during swimming results in its alternate compression and stretching, especially in more caudal regions where these movements are greatest. Moreover, it is probable that the integument of living, swimming cetaceans does not distort as a unit, but that its layers move relative to one another in a way that relates to their inherent rigidity, the orientation of their collagen framework, and the extent to which this fibrous framework is continuous from layer to layer. It is through this very dynamic organ that we are attempting to implant a rigid, stainless steel tag.

Characteristics of Fin Whale Integument Taken in Iceland, 1980

The skin and carcasses of approximately 50 finbacks taken by the whaling station from the period of June 21 through July 9, 1980 were examined during the normal flensing operation. Control (normal) specimens of skin and subcutaneous tissues down to and including portions of epaxial musculature were collected for more detailed "subgross" analysis of integument structure. Examination of these samples was made with the purpose of characterizing the collagenous structures of the integument of this species, as these would provide the primary immediate retaining support for an implanted WHOI/OAR radio tag.

Skin from all surface regions of these whales was examined. Because this experiment demonstrated that only the area between the blowhole and dorsal fin appears to be satisfactory for effective radio tagging (only this region was routinely exposed), the following discussion is limited to this general region.

As described by Ling (1972), 5 integument zones could be distinguished:

1) Epidermis, a deeply pigmented stratified aquamous epithelial layer; in the whales studied here, this was 2-3 mm thick.
2) Dermis, a non-pigmented connective tissue layer supporting the epidermis, richly invested with collagen fibers and gradually transforming below into hypodermis.
3) Hypodermis, a connective tissue layer composed of coarse collagen fibers continuous with those of the dermis. This layer contained a greater porportion of fat, and fewer, thicker collagen fibers

than the dermis. Combined, the dermis and hypodermis of these animals was 5-8 cm thick. Internally, the collagen fibers of the hypodermis were condensed into 1-2 strong, dense sheet(s) of collagen. The number of these depended on the area examined. On the dorsal midline, a single, heavy collagenous sheet nearly 1 cm thick delimited the hypodermis. Off the midline, two distinct collagenous sheets separated by an adipose loose connective tissue (soft blubber layer) were present; the outer of these sheets was approximately 1 mm thick and the inner about 3 mm thick. The soft blubber layer between was 2-3 cm thick. Towards the dorsal fin, the outer sheet was poorly developed or absent; the inner was approximately 3 mm thick.

4) Cutaneous musculature (pannulus mm.). A true cutaneous musculature was absent in the dorsal, "target" area of the finback. The dense collagen sheets described above appeared, on the basis of their location, to be vestiges of the pannulus layer described in other species.

5) Supeficial fascia, an adipose connective tissue layer built upon a sparse meshwork of fine collagen fibers. This layer was 1-2 cm thick, and attached the innermost collagen sheet of the pannulus layer loosely to the underlying epaxial musculature. When skin samples were deformed using lateral, shear-type forces (i.e., parallel to the skin surface), it was this layer that permitted the greatest range of motion. As in other mammals, the superficial fascial layer, therefore, appears to be a major region of the sliding of integument over deep musculature that accompanies spinal flexion.

The radio whale tag is cylindrical, about 29 cm long and 1.9 cm in diameter, and has a special point (Watkins 1979) and attachment projections for implantation and holding in the blubber. The flexible antenna (45 cm long, 0.9 cm in diameter at the base) protrudes from the skin after the tag is implanted. Because of its flexibility and the backward slant of most implantations, there is little drag and only a little motion from water turbulence during swimming. The tag is fired from a shoulder gun and ideally is implanted on the whale's back, no more than a few meters behind the blowhole. This position allows the antenna to be exposed regularly as the whale surfaces. This location is also a region of minimal muscle movement. Depending on the angle of implantation and blubber thickness, the tag may penetrate only into the blubber, or continue into the muscle beneath. Attachments are designed for holding in the deeper layers as well as in the layers closer to the skin.

Normal Skin Responses to an Implanted Tag

The immediate response of whale skin tissues to the implantation of such a tag depends on the extent of cellular disruption caused by the penetration of the tag. The degree of disruption is related to the velocity, mass, and penetration characteristics of the tag. The tag projectile (with pushrod) at implantation weighs 550 gr. and is moving about 60 m per sec. The tip of the point has a 6-mm cutting circle that enables the central tissue to be cut as the tag penetrates and the 20° tapered point (widening to the 1.9 cm tag diameter) to spread the remaining tissue to allow entry of the tag body.

Reactions of Whale Tissue to an Implanted Tag

Without having obtained peri-implant tissue samples from previously tagged whales, as was hoped to be accomplished in this study, an operational understanding of the tissue response of a whale to the WHOI/OAR radio tag is not possible. In particular, the magnitude of the inflammatory response to the trauma of tagging, the temporal relationships of the acute and chronic phases of that response, and the possibility(s) that the implant tract is subjected to ongoing irritation by seawater, mechanical distortion, or infection, cannot be evaluated. Knowledge of each of these will be important to the prediction of tag retention and to the design of modifications aimed at improving retention time.

It can be said, however, that the magnitude and duration of the early or "acute" response of whale tissues to tagging would depend largely upon the extent of cellular disruption caused by implantation. As in other mammals, the acute phase of subsequent inflammation and repair can be expected to result in increased vascular permeability with the release of blood serum factors and white blood cells into the area of injury.

White cells, by releasing lytic enzymes and by engulfing dead cells and damaged matrix, would act to debride the peri-implant tissues of unwanted material. This would tend to loosen the tag. Of special importance is the fact that a large percentage of peri-implant tissue is fat, which tends to liquify following a sufficient inflammatory stimulus. This would act to further loosen the tag. In the uncomplicated case where the tag tract was not subjected to a perpetuating trauma (see below), this acute phase of debridement would be followed by a phase of healing.

As in other mammals, healing would commence with the ingrowth and proliferation of connective tissue cells and capillary vessels along the wound margins, acting to line the tract with a highly vascularized bed of granulation tissue. Growth of this granulation tissue, accompanied by active collagen production by its cells, can be expected to bring the tract wall in closer apposition to the tag, tightening the tag body in place. Continued collagen production would transform this fibrovascular tissue into scar. In the situation where the tag was not held firmly in place by barbs or "hula-skirts", scarification (fibrosis) of the tract depths would tend to expel it to the external environment. This same scarification, however, if occuring around retention mechanisms, would tend to secure the tag, preventing its expulsion. (Such a mechanism may explain historical observations of harpoons that have remained lodged in whales for several years.) Epithelial cells would proliferate along the epidermal margins of the wound, migrating over its outer portions, and eventually, into the tag tract. The final configuration, in the tag's present form, would be that of a cavity, walled with fibrotic connective tissue, and lined by epithelium. It is an eventual hope to modify the tag's surface to permit direct ingrowth of connective tissue and epithelial cells into the tag body.

Potential Rejection Mechanisms

The dynamic nature of normal cetacean skin, the response of this organ to being tagged, and its presence in sea water are all factors which could contribute to loss of the radio tag.

Tag loosening and eventual displacement could result from the mechanical motion created by drag, or water flow, against the protruding portions of the tag. This was believed to be a major cause of the removal of tags implanted in Alaska in 1978 (Watkins, Johnson, and Wartzok 1978). In that study the flange on the tag remained external to the skin and apparently contributed considerable hydrodynamic drag.

Mechanical motion to loosen the tag could also be caused by both muscle contraction around the tag and shear forces created by moving layers of integument. The loose zones of connective tissue present in cetacean skin allow for considerable mobility (Clarke and Ruud 1954). Scar tissue, contracting during the healing process also might accentuate these effects.

Tissue necrosis and the disruption in integument continuity would also contribute to the loss of a tag. Cell damage from the impact of the tag projectile as well as damage created by penetration would lead to necrosis. Infection caused by external organisms carried in with the implanted tag, and aggravated by constant irrigation of the wound with sea water, could also result in cell death. To minimize this problem we have disinfected all tags before firing. Pressures exerted by the tag on the surrounding tissues could lead to cell necrosis and loosening of the implant. These pressures could result from both mechanical motion, as tissue layers moved in apposition, and hydrodynamic drag acting on the tag.

The presence of a foreign body causes tissues to react in an attempt to remove the extraneous substance. The extent of the resulting

inflammatory response is dependent on the composition of the foreign material. External skin cells with their normal resident bacteria if carried in with the tag could cause such a reaction. The shape of the tag's point encourages expulsion of material from its path as it implants, thereby decreasing the likelihood of carrying in external cells. Although the tag itself is a foreign body, its stainless steel components can be expected to be relatively non-reactive in whale tissues.

Analysis of Tag Retention

The 1978 test in Alaska provided opportunity to study the retention of the radio tags in both finbacks and humpbacks (Watkins, Johnson, and Wartzok 1978). These tags were fitted with two 5-cm toggles behind the point and a 5-cm diameter flange as a penetration stop at the base of the antenna. The external flange remained flush with the skin after the tag was implanted. These and all subsequent tags were sterilized with zepharin chloride before implantation.

Although the whales showed little behavioral reaction to the implantation and acted normally thereafter, the tags did not stay in place for long. In the finbacks, the orientation of all the tags changed within the first few hours, and in both finbacks and humpbacks, the tags gradually moved outward with time. The tags remained in the humpbacks for a minimum of 16 days and in the finbacks for up to 18 days. There was no visible evidence of infection around the tags, and there were no scars or deformities seen following the loss of a tag on a finback. The tags moved outward gradually, pulled by hydrodynamic drag. Tissue rejection mechanisms also may have contributed to tag loss.

The 1979 radio tag tests in Venezuelan waters (Watkins, di Sciara, and Moore 1979) were on Balaenoptera edeni, a smaller species than the finback. To reduce the hydrodynamic drag on the tag, the external flange was eliminated and the body of the tag was set 2 to 3 cm below the epidermis. A new holding mechanism ("hula-skirt" attachment, Fig. 3) was added to increase the number and area of holding projections. The tests demonstrated that the modifications had not complicated the penetration characteristics of the tags. During the first few hours after implantation there was no change in tag orientation, the tags were set below the skin surface and the tissues were closed tightly around the lower part of the antenna. This was a definite improvement over the tagging in Alaska. The whales appeared to return to normal behavior soon after tagging. However, the tagged whales were apparently in transit and we could not track for long (engine trouble and little wind for the sails).

For the 1980 Iceland experiment, the tag arrangements tested in Venezuela were used again with only minor modifications. We utilized both the toggles and "hula-skirt" attachments separately and in combination in order to assess any differences in holding capability. A new antenna also was tested and found to provide better low-angle signal radiation, by 6 to 12 dB.

A modification to have been tested was a smaller version of the tag. Although the transmitter for this "hybrid" tag would not be completed, we planned to field-test dummy tags of the smaller dimensions. However, the difficulties encountered in approaching the whales for tagging made each

attempt of vital importance, so that use of live tags rather than dummies had to be emphasized. The firing trials of smaller dummy tags both in Venezuela and in Iceland indicated no difficulties in flight trajectory and with the special points for blubber no penetration problems are anticipated.

Unfortunately, the tagged whales could not be collected (details are noted above), so the analysis of tissues from around the implanted tags was not possible. Tissues from untagged whales were collected and we examined more than 50 fresh finback carcasses to provide a base of comparison. Although the Iceland experiment demonstrated a well working tagging system, future analyses of whale skin tissues relative to transcutaneous tags should be undertaken in order to answer some of the basic questions about tag retention. Regardless of how well a (tag) whale monitoring device remains in place over a short period of time, without knowledge of the dynamics of the tissue reactions we may never have a really long-term tag for satellite or other reacquisition efforts.

New ideas are evolving as a result of the Iceland experiment. We would like to try several methods of more permanently incorporating a radio tag into the integument of whales. Research on human prosthetic devices indicates that various porous materials can be used as scaffolds to promote fibroblastic ingrowth during healing. We need to incorporate the tag as much as possible into the body tissues.

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7. Analysis of the Iceland Experiment

The Iceland radio whale tagging experiment was one of considerable accomplishment. The 2095-km track is a demonstration that the entire tag system performed well. There was no visible detrimental effect of the tag on whale tissue. Although the tagged whales were not caught and analysis of the tissues surrounding an implanted transcutaneous tag was impossible, it was evident from observations of the live whales that the tag implantations remained stable. We saw no hint of infection or rejection over the 10-day tracking period.

The plans and preparations for the entire program appear to have been adequate in every way. In each effort the individuals in charge were careful to insure that we were ready. Sample analysis, photography, tag manufacture, ballistics, tagging, tracking, plotting and field performance was equally high. There was good cooperation between agencies (both in the U.S. and Iceland) and among all of the participants. The limitations were in contingency funding and scheduling to take advantage of unexpected results.

We were able to tag and double-tag the elusive pelagic finbacks. The whales did not react negatively to the tag implantation, though they tried to avoid the maneuvering ship. After tagging, and during the 10-day tracking period the tagged whales and their companions behaved normally. The tagging system was highly reliable in experienced hands. The difficulties we encountered in approaching pelagic finbacks closely enough to tag from a large vessel were unforeseen. We need to increase the tagging range from 30 to 50 m.

Good signals made the tracking highly consistent, and the ADF system worked well. We were able to stay in continuous contact with the tagged whale even in high seas. The choice of frequency was correct for this application. The Iceland to Greenland track provided much new information about finback behavior and this finback population.

A planned improvement to the radio tag is to modulate the signal to allow better identification through ambient noise and for easier automatic signal recording. This should permit signal reception at longer ranges and provide a means for telemetering information.

The radio tags performed well. Their points penetrated straight in line with the trajectories, and the implantation was to the desired depth in the blubber. It was obvious that the location of the tag made a difference in the signal reception. The modifications made prior to this experiment were all improvements. Possible further changes should include a reduction in size of the tag, release of the sharp point from the tag after penetration (to avoid further irritation), and elimination of the collapsible barbs (the "hula-skirt" attachment seems adequate and would further shorten the tag). Addition of telemetry to the radio package would open the way for environmental (depth and temperature) and physiological (heart rate, etc.) monitoring.

8. Summary

The tagging system, the radio tags, and the tracking system all performed well. The 10-day, 2095 km track of the tagged whale in a wide variety of open-sea conditions provided much new information about finbacks. It was difficult to approach the whales within the 30-m range of the tagging system. Tissue samples from around implanted tags could not be collected because of the whale's unexpected travel away from the whaling area. Throughout the tracking period, there was no change in the orientation or implantation of the whale tags, there was no evidence of rejection or infection and the tagged whale appeared to behave and feed normally with one to seven companions. Both tags on the whale were still operating well when tracking was terminated. The 27 to 30 MHz frequencies provided good ADF tracking from ship-mounted receiving systems in all sea conditions to at least 15 km. Maximum ranges were not tested since it was of primary importance to stay with the tagged whale.

Improvements to the system should include increased range for tag implantation and more positive signal identification to reduce confusion with background radio noise pulses (often a problem at all frequencies). Development of efficient aerial tracking antennas for these frequencies would complement the excellent surface-to-surface tracking we now have and would extend the reception ranges (distances of more than 160 km were obtained in testing buoy-mounted radio tags). Analysis of tissue reactions to transcutaneous devices are still badly needed (all of the tag holding mechanisms to date are based on trial and error in only a few field experiments).

A radio tag that permits relocation of the tagged animals from a distance and over prolonged periods will be invaluable in assessing population, distribution, and movement of whale species.

FIGURE CAPTIONS

Figure 1. The Ljósfari, 40.5-m Icelandic capelin fishing vessel (left) was used as the tracking boat. The ADF antenna was welded to the top of the mast approximately 12 m above the water. The tagging vessel, Hvalur 6 (right) was a 46-m whale catcher. (Photo by G. N. di Sciara.)

Figure 2. Six radio tags are shown with a variety of attachments: four have toggles behind the point, three have "hula-skirt" projections on the body of the tag, three are fitted to pushrods over their antennas ready to be loaded in the tagging gun. Visual streamers (folded) are in place on three of the tags. (Photo by K. E. Moore.)

Figure 3. The radio whale tag is shown with its components numbered: (1) point, (2) toggles, (3) tag pressure case (body), two sets (4 and 5) of "hula-skirt" projections, (6) antenna base flange, (7) release couplings, (8) pushrod flange (penetration stop), (9) barrel of shoulder gun, and (10) folded visual streamer. (Photo by W. A. Watkins.)

Figure 4. The radio tag implanted on finback #6. This tag was in a good position on the whale — mid-way between blowhole and fin, 1 m to the right of the mid-line — but was not transmitting reliably so it was not tracked for long.

Figure 5. The "fin" tag on finback #7 was implanted at an angle of approximately 45° from horizontal. Its improved antenna gave stronger radio signals than the neck tag, but was not exposed as regularly. (Photo by K. E. Moore.)

Figure 6. The radio track of the tagged finback is marked with the sequential days of tracking. Navigation was by Loran-C and this track was made from hourly fixes. The whale travelled more than 2095 km as it moved from the Icelandic Shelf to another area about 130 km off Greenland.

Figure 7. A representative plot of signals from both the "neck" and "fin" tags shows the variability in surfacing behavior. This plot covers the period from 0925 on 30 June to 0255 on 1 July. Signal pulses (2/sec) were received during each tag surfacing (two to four or more pulses per surfacing). The base of each slanted line on the plot represents a surfacing time, but no attempt is made to indicate the duration of the signals.

Figure 1

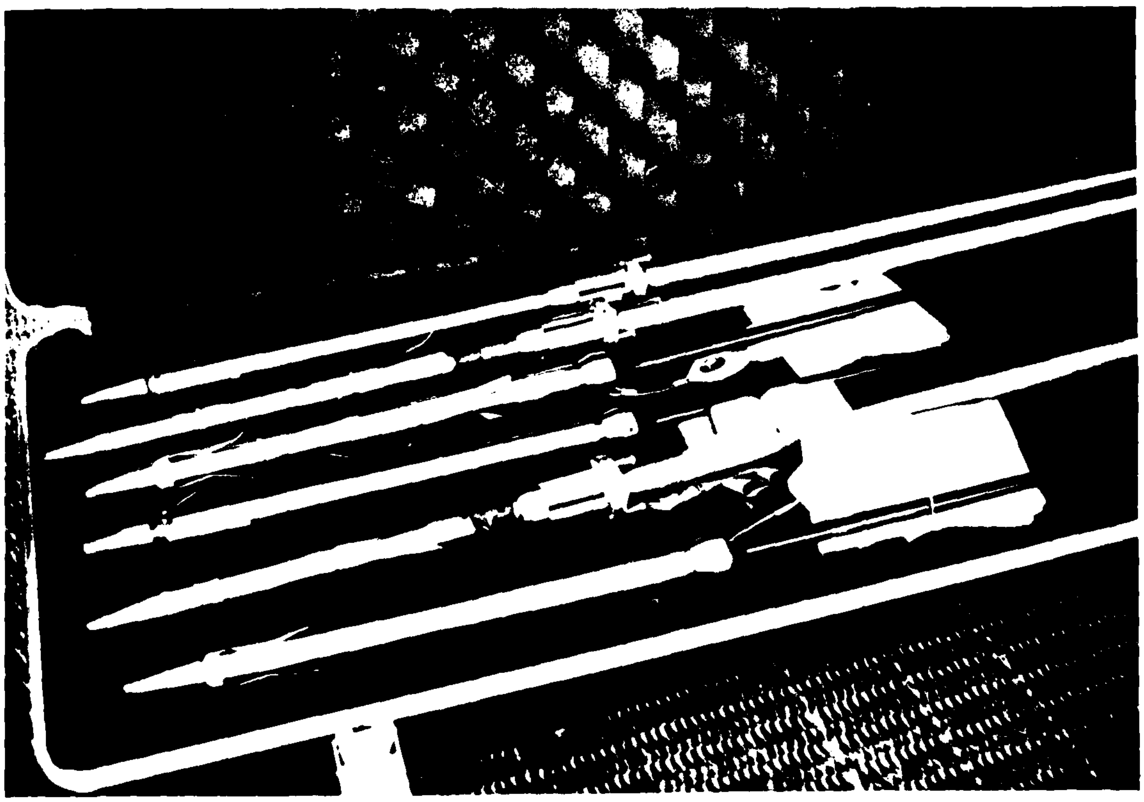

Figure 2

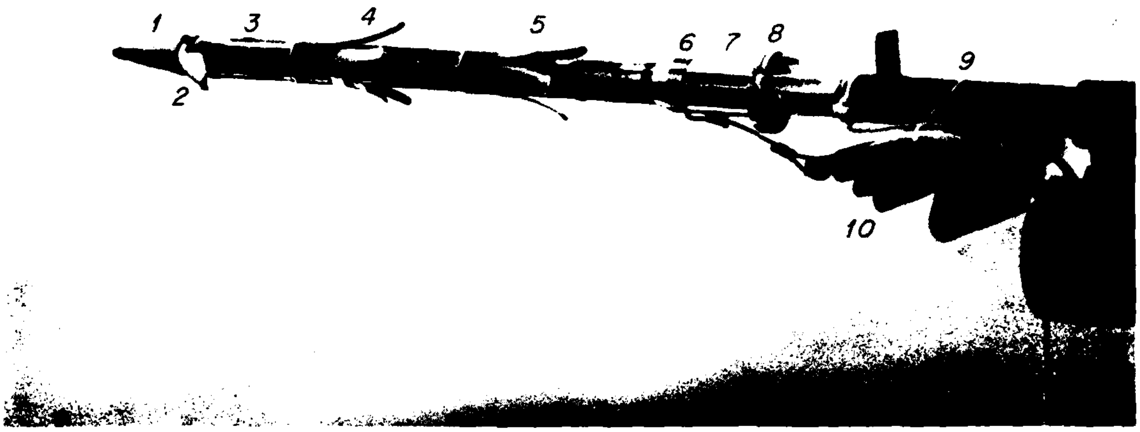

Figure 3

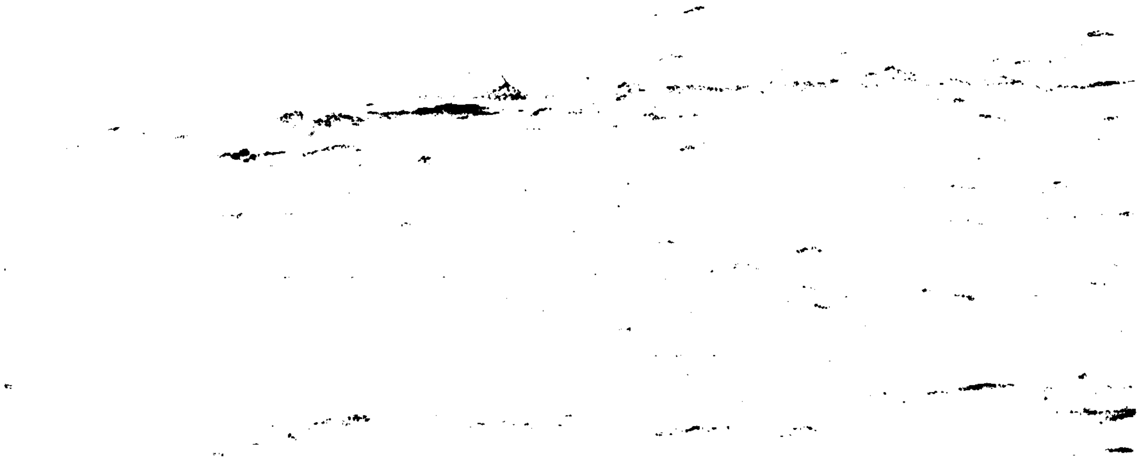

Figure 4

Figure 5

TRACK OF RADIO-TAGGED FINBACK WHALE
25 JUNE – 5 JULY 1980

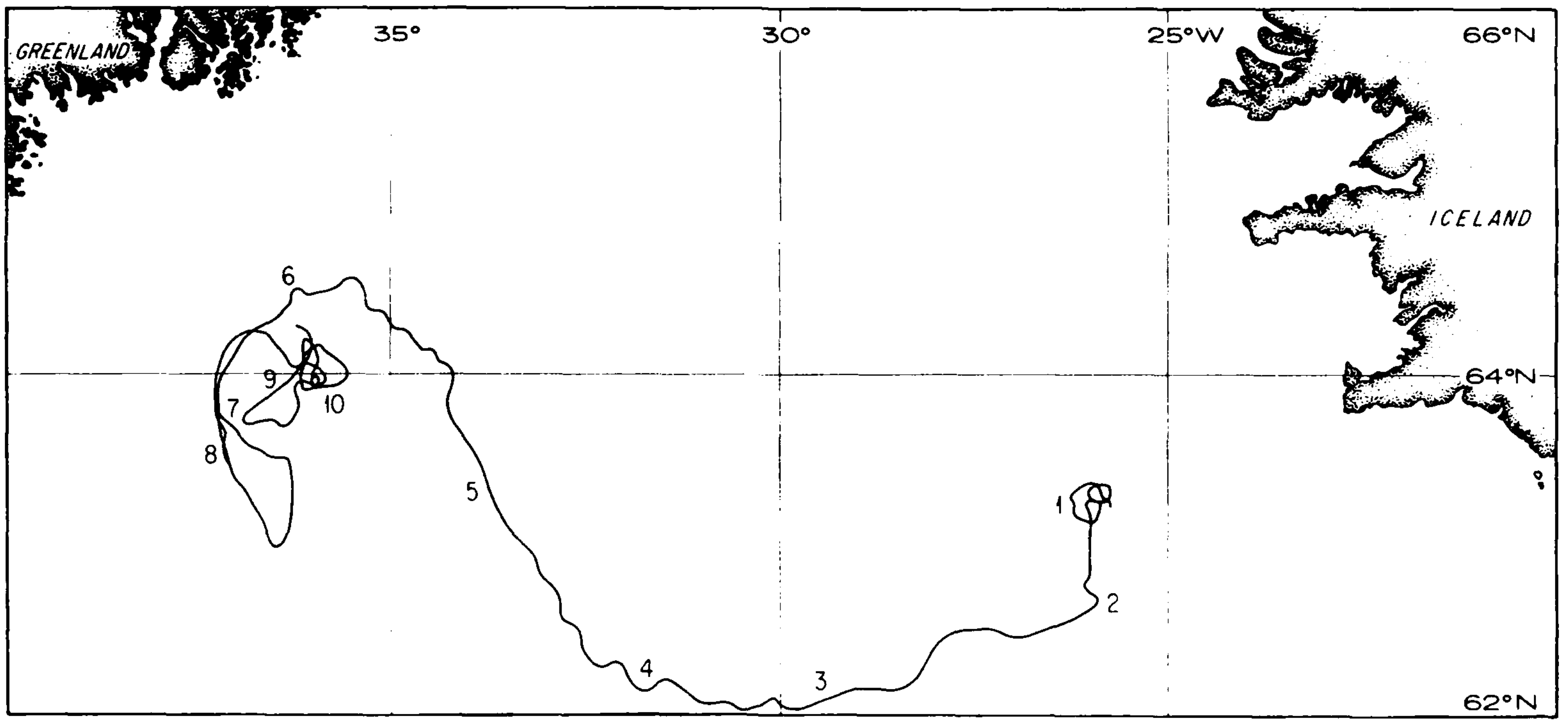

Figure 6

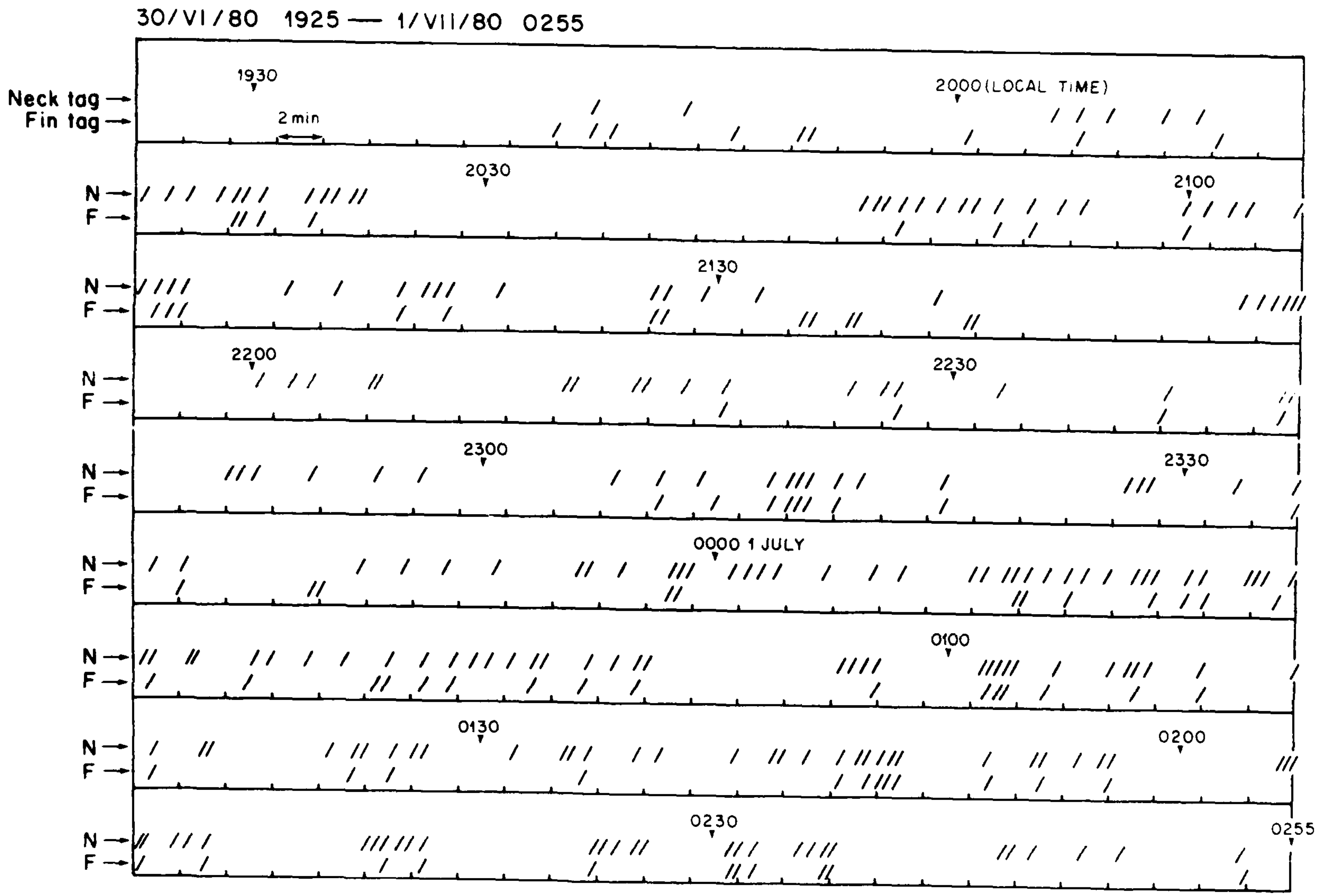
30/VI/80 1925 — 1/VII/80 0255
Neck tag
Fin tag
N
F
2 min
1930
2000 (LOCAL TIME)
2030
2100
2130
2200
2230
2300
2330
0000 1 JULY
0100
0130
0200
0230
0255

Figure 7

TABLE 1

Radio Tag List - Iceland 1980

Whale	Day/Time	Tag #	Radio Freq.	Streamer	Attachment	Implant
#1	24 June 2305	035	27.420 MHz	-	Barbs	Miss, tag lost
* #2	24 " 2310	031	30.170	Orange	Barbs, hula	Left; 3 m ahead, 1 m (from midline)
* #2	24 " "	041	27.520	-	Barbs	Left; 1 m below fin
#3	25 " 0133	025	27.420	Yellow & Orange	Barbs, hula	Richochet, tag lost
#3	25 " "	Short-H	-	Green	Hula	Miss; tag retrieved
#4	25 " 0810	040	27.520	Red	Barbs	Miss; tag lost
#4	25 " "	034	"	Yellow	Hula	Miss; Tag retrieved
#5	25 " 1515	039	"	Orange & white	Barbs	Miss; tag lost
* #6	25 " 1652	037	27.420	Red & Orange	Barbs	Right; midway between blowhole and fin, 1 m from midline
* #7	25 " 2200	036	"	Red	Barbs	Left; base of fin
#7	25 " "	Short-H	-	Green	Hula	Miss; tag retrieved
#8	26 " 0945	"	-	"	"	Richochet, tag retrieved
* #7	26 " 1245	034	27.520	Yellow	Hula	Right; 3 m behind blowhole, 25 cm from midline
#7	26 " "	Short-H	-	Green	Hula	Richochet, tag retrieved
#9	26 " 2050	"	-	"	"	Miss; tag retrieved
#10	3 July 1740	"	-	"	"	Richochet, tag lost

We tried to tag ten whales. Tags that were successfully implanted are starred.
Whale #7 was the whale we tracked.

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RADIO TAGGING OF FINBACK WHALES ICELAND, JUNE-JULY 1980 by William A. Watkins. 46 pages. January 1981. Partially funded by the Bureau of Land Management of the U.S. Department of the Interior under Contract AA851-CTO-23 and the Oceanic Biology Program of the U.S Office of Naval Research under Contract N00014-79-C-0071, NR 083-004, and the Marine Research Institute of Reykjavik, Iceland and the Iceland Whaling Company.

In June and July, 1980, finback whales (Balaenoptera physalus) were radio tagged in the waters west of Iceland. One double-tagged finback was tracked continuously with shipboard receiving gear for 9 1/2 days, for over 2095 km, during which it swam with from one to seven companion finbacks to within 130 km of Greenland. The tagging and tracking systems worked well. New behavioral information about finbacks was gathered, and new questions were raised concerning this population's movements and and distribution. Whale integument is discussed and the potential retention of transcutaneous whale tags is analyzed.

1. Radio whale tag
2. Tracking of radio tagged finback whales
3. Balaenoptera physalus

I. Watkins, William A.
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RADIO TAGGING OF FINBACK WHALES ICELAND, JUNE-JULY 1980 by William A. Watkins. 46 pages. January 1981. Partially funded by the Bureau of Land Management of the U.S. Department of the Interior under Contract AA851-CTO-23 and the Oceanic Biology Program of the U.S Office of Naval Research under Contract N00014-79-C-0071, NR 083-004, and the Marine Research Institute of Reykjavik, Iceland and the Iceland Whaling Company.

In June and July, 1980, finback whales (Balaenoptera physalus) were radio tagged in the waters west of Iceland. One double-tagged finback was tracked continuously with shipboard receiving gear for 9 1/2 days, for over 2095 km, during which it swam with from one to seven companion finbacks to within 130 km of Greenland. The tagging and tracking systems worked well. New behavioral information about finbacks was gathered, and new questions were raised concerning this population's movements and and distribution. Whale integument is discussed and the potential retention of transcutaneous whale tags is analyzed.

1. Radio whale tag
2. Tracking of radio tagged finback whales
3. Balaenoptera physalus

I. Watkins, William A.
II. AA851-CTO-23
III. N00014-79-C-0071; NR 083-004
IV. Marine Research Institute, Reykjavik, Iceland
V. Iceland Whaling Company

This card is unclassified

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